Consequences of agro-biofuel production for greenhouse gas emissions

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Risks and benefits from bioenergy – a Nordic perspective in a global context
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Globally agriculture and forestry faces fundamental challenges during the 21st century. These challenges are primarily associated with the need for drastic increases in production of food, fiber and bioenergy and at the same time considerably reducing the environmental footprint of the production (e.g. reducing contribution to eutrophication and global warming).

The global population is expected to increase from 6 to 9 billion people in the period until 2050. At the same time increasing wealth in the developing countries will mean higher food consumption and also higher consumption of forestry products per capita. This is expected to lead to a doubling of world meat consumption and an increase of 60% in world cereal consumption from 2000 to 2050 (FAO, 2006b).

The global agricultural area constitutes about 5 billion ha (37% of world land area). Of this 70 % is permanent pasture. The remaining 11 % of the global land area is used for annual and perennial crops (everything from cereals to wine and walnuts). It is estimated that a further 2.6 billion ha land area can be utilized for production of agricultural crops. However, in reality many of these soils are less suited due to low fertility, high ecological vulnerability and lack of infrastructure. Also a large part of this area is currently in forest or peatland, and cultivation will be associated with large environmental consequences in the form of biodiversity loss and greenhouse gas emissions. There are therefore good reasons for concentrating the production on the existing agricultural land and increasing crop yields.

Along with an increasing demand for food there is also a rapid increase in demand for bioenergy and biofuels. According to the definitions by FAO (2006a) bioenergy is defined as energy from biofuels, and biofuel is fuel produced directly or indirectly from biomass such as fuelwood, charcoal, bioethanol, biodiesel and biogas. The increasing demand for biofuels is driven by high oil prices, and the consequences have been that commodity prices within agriculture to a large extent have been coupled to the oil price. High oil prices increases the demand for biofuels and this means that a part of the agricultural area is used for bioenergy instead of food production resulting in increasing food prices. In combination with poor harvests and the economic crises this has caused world hunger to reach a historic high of more than one billion people in 2009. Not only food prices are increasing, but so are the prices for the agricultural inputs such as fertilizers and pesticides.

World oil reserves are declining, whereas demand continues to increase over time, and it is expected that there will be increasing difficulties in satisfying the demand for oil and other liquid fuels (IEA, 2008). This will increase the pressure for agriculture and forestry to contribute to increased production of biofuels. To avoid pressure on biodiversity and greenhouse gas emissions such a production should take place without clearing existing forests and cultivating other vulnerable nature areas. At the global scale there are (unfortunately) many degraded lands that are less suitable for agricultural production, but where a suitable biomass production for biofuels could take place. This requires use of biomass crops that have high productivity, low water use and little requirements for fertilizers and pesticides. The cultivation of bioenergy crops on existing agricultural land can probably not be
avoided, which increases the needs for increased yields of food crops to satisfy the
increasing food demand. Recent studies have pinpointed the risk that using
agricultural land for bioenergy production may cause clearing of natural areas in
other parts of the world leading to significant GHG emissions (Fargione et al., 2008;
Searchinger et al., 2008).

In addition to the increasing demand for food and biofuels there is also an increasing
focus on agricultural resource use and environmental impact. Agricultural soils are
being degraded in many parts of the world, including Europe. This is in particular the
case for arable land, but can also occur for overgrazed pastures. It is in many cases
particularly important to ensure a large return of organic matter to the soil to
maintain soil fertility, e.g. through plant residues and manures. This means that
there are limits to how much of the agricultural wastes and residues can be used for
biofuels. The cool climates in the Nordic countries probably allows for a larger
extraction of crop residues than under warmer climates. About 80 % of global
freshwater abstraction is used for irrigation in agriculture. In many parts of the world
this leads to overabstraction of water caused reductions in groundwater tables and
drying out of rivers, streams, lakes and wetlands. Since climate change will in many
places lead to a more extreme precipitation climate with longer and more severe
droughts this increases the need for increasing water use efficiency of plants through
more efficient irrigation techniques, water saving cultivation techniques and drought
tolerant crops and varieties. This applies to both food and biofuel crops.

Agriculture affects the environment through pesticide use, nutrient losses and
emissions of greenhouse gases and through cultivation and draining of new land
(Tilman, 1999). The pesticide use leads not only to consequences for pesticide
residues in food and direct effect on agricultural laborers, but has also effects on the
surrounding environment through losses to both terrestrial and aquatic
environments. Loss of nitrogen and phosphorus to the surrounding environment
leads to eutrophication, and is also a loss of essential nutrients. It is thus estimated
that the global reserves of phosphorus will be exhausted within about 60 years. In
the aquatic environment these nutrients lead to algal blooms, anoxia, fish death and
loss of biodiversity, and these problems are growing at the global scale (Erisman et
al., 2008). Agriculture is also a major contributor to greenhouse gas emissions and
responsible for 14-30 % of the anthropogenic contribution to global warming. The
uncertainty range in this estimate represents uncertainties in how large a part of the
emissions from deforestation can be attributed to the expanding agricultural area.
Solving these problems requires a considerable increase in resource efficiency of
agricultural and biomass production and an end to deforestation and cultivation of
peatlands for agricultural purposes.

Proper agricultural management and land use planning will allow a substantial
allocation of land area to bioenergy production, primarily of environmentally
vulnerable or degraded land areas. In the Nordic and Baltic region, it will probably be
particularly interesting to grown perennial bioenergy crops in nitrate vulnerable zone
and other perennial energy crops in areas that need to be maintained as wetlands or
to protect peatlands. The cool climate in the Nordic countries will also allow use of
straw and other residues for bioenergy, in particular if this combined with growing
catch crops to enhance soil carbon inputs.

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Nature Geoscience 1, 636-639.


The EU-Agrobiogas project. By Dr. Thomas Amon

Systematic approach for successful acquisition of EU funding for energy-related projects.
By Andreas Moser
Farm biogas in Italy: situation, problems, prospects
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Anaerobic digestion of animal wastes has started to become a reality in Italy since the end of 1980 in correspondence of the Gulf crisis. At that time more than 100 biogas plants mostly of low power (<100kWel), were built. Due to the decrease in interest in biogas production of the following years, only few of them (<20%) are nowadays still running. Due to the recent increase of fossil fuel prices, since year 2000 the anaerobic digestion of feedstock and animal manures has came back to be of great interest.

In Italy, at present, more than 200 anaerobic digestion plants are running or are in an advanced building stage. Half of them are still farm-scale anaerobic digestion plants with an average installed power lower than 100kWel.

The most common plant typology of these biogas plant is represented by completely stirred reactor tanks, operated in mesophilic conditions and with HRT shorter than 40 days. From 2004, thanks to the national incentives for the renewable energy production, bigger biogas plants (800-100kWel.) have been built and fed with animal manures and energy crops. According to a recent survey carried out by DEIAFA – Torino University - the most common weak points of A.D plant in Italy concerns the equipments for fermenter feeding and stirring. Most of the plants run at full capacity for 5500 hours per year only vs. 7000 planned hours (8760 hrs as potential) with a yearly economic loss of 420.000-920.000 Euro for a 1MWel. installation.

With the aim to improve the performance of anaerobic digestion plants, in the ambit of EU Agrobiogas project, some modifications to a 1MWel. biogas plant (Bagnod Plant) were done:
   a) reuse of the solid fraction obtained by the mechanical separation of digestate;
   b) improving of the use of heat produced by the CHP and,
   c) coverage of the liquid fraction storage tank and recover of the residual biogas.

Thanks to the mechanical separation of digestate and the reuse of the solid fraction as a feeding material it has been possible to improve the biogas yield of the Bagnod digestion plant of approximately 12%. An appropriate use of the heat produced by the CHP (at present more than 40% of the thermal energy is lost) could allow the yearly drying of 7000t of the digested solid fraction (75% relative humidity) and 40000t cereals grains (26% relative humidity). The coverage of the digestate storage tank (1017 m², 6000m³ volume) allowed to avoid the daily emission in the atmosphere of approximately 12.5kg NH₃ and 2.6t of CO₂eq. from the whole storage. In detail, the residual biogas recovered by the storage tank accounted for the 27% of the total GHG emission of the Bagnod plant. Furthermore, by the recovered biogas (250-500Nm³ per day) it is possible to increase the daily plant biogas yield of about 2-4% (0.5-1MWhel.). According to these latter results, in anaerobic digestion plants the storage of digestate plays an important role under the environmental point of view. The coverage of storage is therefore strongly recommended.
Current state of biogas production in Germany.
By Dr. Helmut Döhler
Oral Presentations

On-line measuring on a bio-gas plant - what can be achieved?

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_English version by Hans Peter Hansen, ScanTronic ApS, hph@Scan-Tronic.dk_

The results from a bio-gas installation are decisive determined by the quality of the produced bio-gas and analyses of the gas quality become more and more in focus by a profit orientated management.

Professionals and external companies are moving. And the personnel cost to get proper data values demand efficient gas-analyse on-line, away from the unfortunate up to now practised “flash measurements” with spot-values towards interpretive presentation of a time and location fixed sequence of gas-component values.

Messtechnik EHEIM GmbH have since 2002 gathered experience on biogas plants and can today - at an acceptable and reasonable investment cost offer equipment for praxis-orientated analyse that fulfill the required and generally accepted demands listed below:

- Measuring ranges for gas-components must cover all problem situations (CH₄ and CO₂ up to 70%, O₂ up to 25%, H₂S up to 5.000 or better 10.000ppm, H₂ up to 10.000 ppm).
- Long continual measuring values inside ranges – also abnormal process values may not substantial reduce accuracy.
- Continual measuring over several hours must be possible. During this tiny trends together with measuring values elsewhere in the system must be recorded for comparison. During this process no zeroing or calibration must be necessary.
- Additional measured values that can improve the creditability of data or illustrate abnormal operational conditions shall be a real option.
- Measuring values shall at any time be testable for plausibility. When not - a local and fast calibration must be possible.
- The data must be presented in way that gives a clear visualisation of even small changes in process conditions. Without interrupting the actual measurement recording, visualisation of prior data must (at any time) be available for evaluation.
- Events and data must be journaled in a way that easy enable a later assignment to specific process reaction or events.

Following 9 practical example where on-line diagnostic have been a decisive help for bio-gas plant in 3 situations:

- On failure recognition
- Optimizing performance
- Screen plant behaviour

Gas-analyse as failure-recognition in bio-gas plants

Example 1 The methane concentration of a gas feed into a gas motor gave reason to concern. Two daily spot measurements showed stable values but a continuous registered measurement showed abrupt CH₄-changes of 10 to 15 Volume %.

An investigation revealed that the gas-pipeline years ago had been moved and renewed. A blind end have unfortunately been forgotten and where now so corroded that air was leaking in by vacuum condition.
Example 2 Occasional concentrations of 1.800 ppm H₂S at the input stopped the gas-motor. This high concentration at the fermenter could only be reproduced turning on the agitator.

A continuous registration of CH₄ and H₂S showed peaks disturbing the trend of H₂S. The remedy was a better strategy for the use of the agitator and afterwards a better control of the air for the biological H₂S reduction. Result the H₂S was reduced down to 15 %.

Example 3 A plant have regular raised H₂S values every morning at 10 o'clock, a peak value of 600 ppm at 13 o'clock and returns below limit at 18 o'clock. A discontinuous “spot” measurement gave no indication of a problem but nevertheless the oil of the motor had to be changed so often that a troubleshooting service had been ordered - after a pair of motor breakdowns had occurred. Unfortunately for this lecture the customer did not want to spend money for further analyse so we may hope that they have found the error themselves.

Gasanalyse to optimize bio-gas plants

Example 4 This example cover a “short” CH₄ measurement lasting a total of 1,5 hours on two serial connected fermenters. The example is used to warn for fast conclusions. The fast expressed optimizing thesis, was that the two fermenters could be interchanged due to a better biology in the first one but a carefull evaluation of the average CH₄ output was the decisive parameter – remembering to account for the excess air of the H₂S reduction.

Example 5 (see fig. 8) show the progress in CH₄ and CO₂ during optimizing of a horizontal fermenter. To correct the values for the not yet known humidity, the gas-analyser have recorded the temperature of the condensate separator. After data export from Win-Data this temperature have been used to forward calculate the CH₄ and CO₂ values to dry condition. Over the entire registration lasting approximate 3 hours the temperature raised from 10 to 20°C with large peaks. This means high change and fluktuations of the humidity percentage in gas. This again dilute the CH₄ and CO₂ values. The second curve-sheet with compensated CH₄ and CO₂ values show quite some difference and give a better background for optimizing tasks.

Example 6 A fermenter feed with energy crops over 30 days show highly variating CH₄ and CO₂ concentration. A strict counteracting of CH₄ and CO₂ values (whereas excess oxygen and gas-temperature are fairly constant) indicate a problem in the biology. Analysing the values day by by confirm this. Opposite the constant 51 % CH₄ value during the day - this falls to 43 % during the night due to overfeeding.

Gasanalysis to screen the behaviour of biogas plants

Example 7 Profile of a bio-fermenter (concentration of CH₄ and H₂S) during 3 month. The data was recorded to be background for evaluation of the biological and plant-technological situation of the plant together with desire to a proposal for needed instrumentation.

Example 8 Identify the behaviour of a gas-washer in a plant fermenting mash. The function of the washer are identified by the H₂S concentration between 100 and 500. One problem pointed using a washer are how to handle the gas when the system is stopped and later have to be started again. Example 9 A 3 week recording of the raw gas at a plant fermenting domestic waste - to get a background to layout a gas preparation. The typical high H₂S values for this kind of substrate are clearly indicated and the measuring equipment for this job include a 10.000 ppm H₂S channel.
Summary
The purpose of on-line gas-analysers is to remove uncertainty of gas concentrations, find error sources, maximize CH₄ output, minimize H₂S load, find typical working ranges, and find operating characteristics/functionality of total systems and part elements. The on-line gas-analyse can and will only contribute to the efficiency of bio-gas plants when rapid and interpretable measured data leads to professional and economic founded decisions for design, operation, maintenance and optimization of the plants. This support can only be obtained using continuous measuring gasanalysers combined with data-software that offer graphical on-line evaluation and presentation.
AGROBIOGAS - An integrated approach for biogas production with agricultural waste

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Biogas production based on agricultural waste is a cost-effective way of reducing greenhouse gas emissions and at the same time it benefits both farmers and the environment in several ways. The purpose of the AGROBIOGAS project is to promote biogas production throughout Europe by developing a complete anaerobic digestion (AD) toolkit to aid the decision making of farmers considering establishing a biogas plant. In addition the AGROBIOGAS Toolkit can be used to optimise existing plants.

The core element of the AGROBIOGAS Toolkit is a stand-alone software application comprising a substrate (biogas feedstock) database and a simulation tool. The Toolkit user is able access to a wide-range of quantitative and qualitative information for up to 30 different substrates, at present. This includes, for example, the geographical availability of a feedstock, as well as standard chemical and physical characteristics, such as nitrogen content or percent dry matter. The database also contains comprehensive data from batch and continuous lab-scale experiments carried out during the AGROBIOGAS project on a selection of the substrates included in the database.

The simulation tool is the central component of the toolkit and acts to predict the AD outputs given a number of pre-defined system inputs (e.g. feedstock characteristics) and states (e.g. biogas plant process parameters). The user specifies the type and quantity of substrate(s) to be used in the simulation, together with key process parameters of the biogas plant (e.g. reactor size, temperature, HRT etc.). The simulation is based on an adapted version of the Anaerobic Digestion Model No. 1 (ADM1) and the outputs from the model consist of 71 parameters characterising the modelled biogas process reached at steady-state (e.g. methane yield, pH, ammonia, inhibition effects). The outputs from the simulation can be graphically displayed to the user for comparison between several process simulations, providing some potential to analyse the performance of the plant under different operating conditions. Some of the achievements of the AGROBIOGAS Simulation tool compared with other simulation tools are that this tool takes into account the effect of co-digestion and that validation is done using data from a number of large-scale biogas plants. There is also a possibility to perform looped simulations that allow for interpretation of plant performance when inputs or process parameters are changed. The result is a very powerful simulation tool to be used both for planning and educational purposes.

Information from the Toolkit may be used by the Agrobiogas Investment Decision Tool (IDT) to facilitate a first economic evaluation of a given biogas project under the conditions specified in the Toolkit. Based on the specific substrate mix selected (amounts and costs) and taking into account the capital and operating costs together with the local price of electricity and heat the internal rate of return of the project
and the payback period are calculated. This is useful information for European farmers who are considering participation in a biogas production scheme or developing their own plant.

Also included in the AGROBIOGAS Toolkit are the operational guidelines including a troubleshooting section and advice on how to undertake effective process control. A further element comprises recommendations on utilisation of AD sludge as biofertiliser to secure optimal storage, handling and application of AD sludge so that the wanted benefits for the farmer and environmental will actually be achieved.

All tools in the AGROBIOGAS Toolkit are gathered in the European AD Helpdesk which is available on the website www.adhelpdesk.eu. The Helpdesk provides information about technical, economical and regulatory issues both for farmers considering establishing biogas plants and for owners of existing plants. In a first step the AD Helpdesk is mainly targeted at users in Spain, Germany, Slovakia, Greece, Italy and Denmark and biogas experts in these countries can be contacted via the Helpdesk. Further dissemination activities (to East European regions, for example) and strengthening of the tools to provide more robust results and a wider range of available inputs and outputs, are ongoing or expected.
Critical sampling and choice of equipment in bioreactors

Anders Larsen, CEO, Q-Interline A/S, Denmark

To optimize the yield of a bioreactor, monitoring of critical chemical components is essential. A bioreactor is a three-phase system, and to sample a such is not trivial, neither is the choice of sensor technology. Only when a proper sampling system is applied combined with use of suitable sensors, meaningful data can be extracted and form the basis for a regulation to achieve higher load and yield.

The presentation will highlight pitfalls and challenges in sampling the gas phase and the liquid/solid phase, and it will propose practical guidelines for successful extraction.

Case examples of the use of highly sophisticated analysers like FTIR and MS for the gas phase and FT-NIR for the liquid/solid phase and how to apply these in real life will be included in the presentation.
Improvement of the Efficiency of Agricultural Biogas Plants by Mashing the Co-Ferments

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The project EU-AGRO-BIOGAS is a European biogas initiative to improve the yield of agricultural biogas plants. One of the main technologies which are currently not optimised is the feeding technology to bring in the substrates. The disadvantages of the hitherto existing methods of feeding the digesters of biogas plants are high energy consumption conditional on frequent mixing, high labour costs due to the use of mixing pits and slow decomposition of biomass because of dry-feeding of co-ferments.

Being a participant of the European project EU-AGRO-BIOGAS, Vogelsang develops and analyses innovative feeding technologies to improve biogas yield and energy output at more competitive costs.

For this purpose a mixing/feeding unit has been developed, which combines the operations of disintegrating, mixing and feeding of co-ferments and liquid manure. The organic dry matter is supplied into a double-toothed screw conveyor, e.g. by a vertical mixer. At the same time the liquid manure is supplied by a separate manure pump. The mixing screw disintegrates the coarse material and feeds a rotary lobe pump after transforming the dry matter and the liquid into a homogenized, high viscous suspension. A cutting process can be added. So several digesters in biogas systems can be supplied continuously with well prepared co-ferments. A mobile mixing/feeding unit is presently being tested throughout Europe under the most different conditions.

Two stationary mixing/feeding units are being tested intensively at two biogas plants in Lower Saxony at present. At one biogas plant, the labour and energy consumption is analysed by comparing the results of the mixing/feeding system with the results of a conventional mixing tank. At the second biogas plant, the energy consumption of the stirring units and the gas yields of two identical digester arrangements are being measured. One arrangement is conventionally dry-fed, the other one is fed by a mixing/feeding unit. The first test results at both biogas plants are very promising. So swimming layers and emission of bad odour could be reduced. Also this system shows the ability to handle a wide range of co-ferments, which is of rising interest. And the labour and energy consumption could considerably be reduced as well as the hydraulic retention time.

Additional treatment of the co-ferments like cutting, ultrasonic treatment, hydrolysis or mixing in additives like enzymes, which may increase the gas yield, can easily be applied if the co-ferments are mixed with the fluid before entering the digester. Both existing and new-built biogas plants can be equipped with this new mixing/feeding technology. Due to the improved feeding technology the economical and ecological benefit increases.
Harvest and handling of perennial energy crops – Danish experiences

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The growing of perennial crops might give essential environmental advantages. Willow and miscanthus is the perennial crops, which have been in focus in Denmark. They have a high yield potential, low need of fertilizer and in an established crop there are none or very little need of pesticides. Both crops are able to reduce the leaching of nitrate and thereby protect the ground water. So far willow is the only crop grown on a commercial scale.

For both crops rational techniques and systems for harvesting, handling and transport are decisive for the economy. The field harvesting techniques must fit into the techniques used subsequently by the end users (Sambra, 2008 and Huisman, 2000). Is the crop for combustion, the typically end user will be heating plants or combined heat and power plants (CHP plants). Biomass combusting plants are often designed for combustion of big baled dry straw or wood chips, and therefore the willow and miscanthus must be delivered in big bales or as chips.

Willow is normally harvested in the period from November until March when the moisture content is relative low. In Denmark harvest at that time of the year can be difficult due wet weather conditions and no frost. In order to secure the harvest and a stable supply of willow during the harvest season full-track machines and vehicles are to be preferred. Summer harvest has been tested, but that will effect the quality for combustion negatively and remove more nutrients and minerals from the field.

In principle two different harvest methods are used, - combined harvest and chipping or whole shoot harvest, see figure 1.

Today harvest and chipping technology is in constant progress, but still mainly dominated by different prototypes and none in reality commercial technologies. In Denmark combined harvest and chipping is the most common used technology, but also whole shoot harvest is used. Using the current machines and methods, combined harvest and chopping is cheaper than whole shoot harvest and post-harvest chopping (Styles et al 2008 and Scholz et al. 2008). However, whole shoot harvest have advantages in terms of a flexible harvest and supply chain (Kofman et al., 1997) and possibilities for low cost drying (natural wind drying) and thereby an improved fuel quality (Harders, 2002).

The interest for whole shoot harvesting and production of a dry chip has increased; and today, this concept is seen as one way of improving the economy and
Optimising is strongly needed in harvest technology and within the whole supply chain to fulfill the quality demands and security of supplies stated by the end user.

Miscanthus can be harvested by use of existing machines for straw, maize or grass. In some cases modifications will be necessary. However when large areas are to be harvested it will be beneficial to improve the machines or even to design new machines better fitted for handling this very sturdy and stiff-strawed type of crop (Kristensen 2001).

Harvesting may take place in the period from October/November when the crop has passed the ripening stage and until the following spring when the plants again begin to sprout. The combustion quality depends on the time of harvesting. The moisture content of the crop will decrease from 60-70% in the autumn to less than 20% in spring. During the winter, the plant loses its leaves, and mineral leaching from the straw due to rain will take place. The best fuel quality will thus be obtained from spring-harvested miscanthus (so called delayed harvest). In spite of the low fuel quality winter harvesting may sometimes be an advantage, because of the higher yield of biomass. Moreover, winter harvesting may permit direct delivery to a heating plant.

In Denmark investigations and tests have shown that the following machines and machinery chains can be used for miscanthus harvest:

- Exact chopper with row independent maize header
- Mower and subsequent collection with exact chopper equipped with pick-up
- Mower and subsequent collection with big baler
- Big baler mounted with chopper
- Exact chopper and big baler in one unit

All the above-mentioned techniques are applicable for spring harvesting, but the big baling system is unfit for winter harvesting, due to the high moisture content.

Conventional disc mowers equipped with crimpers is applicable for mowing. The capacity will be lower than for mowing of grass and grain.

Both self-propelled and trailed exact choppers can be used for miscanthus harvesting. For direct harvesting, row-independent maize headers will be suitable. An advantage of harvesting with exact choppers is that the material will be applicable for direct use in automatic stokers and at chip combusting plants. A rational method of harvesting and delivery will be harvesting by means of exact chopper with container platform and transport of the filled containers to the heating plant by means of lorry. The density of chopped miscanthus is very low, i.e. about 80 kg of dry matter/m3. This will be a disadvantage in a handling situation, especially in the case of long distance transport.

Properly mowed miscanthus can usually be collected and baled without problems by means of big balers. The baling capacity will be lower for miscanthus than for straw, because the structure of the material (long and stiff) may cause stops of the pick-up and the feeding mechanism. Net capacities of about 16 tonnes of fresh weight per hour have been observed. The density is 140-170 kg/m3.

Big balers mounted with choppers can be used for simultaneous harvesting and baling. The advantage of the big baling methods will be that the subsequent handling and transportation can be performed in a rational manner. The system for delivery of
big baled straw to heating plants and CHP stations is well known and well established.

References


Energy efficiency of cultivation and use biomass of perennial grasses for biogas.

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An opportunity to reach high yields is not sufficient measures to cultivate energy plants. Energy and environmental efficiency might be accepted when energy inputs are lower than energy outputs during all cycle of energy conversion of energy biomass (Boerjesson P.).

Technology of biogas production from energy plants biomass has several steps of biomass production, treatment in anaerobic environment and utilisation of digestate. The aim of the present study was to evaluate perennial grasses as a bioenergy crops. Energy consumption for plant cultivation and harvesting, biomass treatment and storage was studied.

Field and laboratory tests of Phalaris arundinacea and its mixtures with legumes Galega orientalis, Lupinus polyphyllus, Melilotus officinalis and their biomass utilisation for biogas production were carried out at the Lithuanian Institute of Agriculture and the Lithuanian University of Agriculture. The swards were grown on a light gleyic loam soil (Cambisol). Pure swards were fertilised with N60+60, and two-component mixtures did not receive any N. The swards were cut twice per season. The first cut was taken in the middle of June and the middle of July, the second cut was taken simultaneously - at the end of September. Samples of freshly-mown grass, dried biomass and silage were treated on laboratory scale biogas digesters under mesophilic conditions (Kryzeviciene et al., 2005).

Energy potential of swards was calculated according to the herbage DM yield and biogas yield, extracted from biomass on laboratory scale digesters. Biogas energy value was estimated according methane concentration in biogas. Pure Phalaris arundinacea, applied with N60+60 yielded significantly best of the four swards differing in species composition grown on a light soil, low in humus (up to 2 %) only when 1st cut had been taken in June. The total yield of pure stand and mixtures with Galega orientalis Mix-3 was not significantly different when 1st cut had been taken in July. Averaged annual DM yield amounted to 9.2 t ha-1 (Kryzeviciene et al., 2006).

Pure Phalaris arundinacea and its mixtures with Galega orientalis were found to have the greatest energy potential, 130-138 GJ ha-1, of the four swards differing in species composition, whose biomass was used for biogas production (Kryzeviciene et al., 2007).


In average the energy input for cultivation is 37,1 %, preparation - 21,4 %, storage - 5,6 % and digestion 35,9 % (Navickas et al., 2006).
References


Strip intercropping strategy for biomass to energy production while on the same time maintaining soil fertility

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In contrast to energy technologies like solar and wind, energy in the form of biomass can be stored and bioenergy produced when needed using a wide range of technologies. However, a substantial rise in the use of biomass for energy is expected, which means additional pressure on farmland sustainability. Organic agriculture (OA) is facing a big challenge producing bioenergy from local resources and on the same time maintaining soil fertility. There is a clear goal to reduce reliance on fossil fuels and thereby decrease greenhouse gas emissions, but the question is how to reach it? In a four year ICROFS (www.icrofs.org) project titled “BioConcens” (www.bioconcens.elr.dk/uk/) one objective is to design and test a strip intercropping concept.

Strip intercropping (IC) is based upon general IC principles focusing on the management of plant interactions to maximize productivity and resource utilisations (Willey, 1979). The crops are not necessarily sown and harvested at the same time, but the crops co-occur for a significant period of their growth. IC is a practice with crops grown in strips wide enough that each can be managed independently, yet narrow enough that the strip components can interact. This kind of cropping strategies was common in developed countries before the ‘fossilisation’ of agriculture (Matson et al., 1997) contributing to yield stability and soil fertility, lowering nutrient losses and reducing weeds, diseases and pests (Hauggaard-Nielsen et al. 2007).

The field experiments were designed to deal with cropping diversity in time and in space. A diversified perennial grass-clover strip (feed, energy (biogas and bioethanol) and soil fertility building) and a strip consisting of either i) winter rye + winter vetch intercropping or ii) maize was established (food, feed and energy (biogas and bioethanol)). Winter rye was sown before maize to capture growth resources during autumn and early spring. The annual strip was initiated in September by winter rye (+ vetch) and finalized in august 2 years later with harvest of triticale (see table below). The strips were 5 meters wide with all mechanical operations conducted using traditional farm machinery.

Table 1. Strip intercropping concepts comparing two annual cropping systems

<table>
<thead>
<tr>
<th>Time (mth)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity in space</td>
<td>Winter rye + vetch</td>
<td>Triticale</td>
<td>Winter rye + vetch</td>
<td>Triticale</td>
<td>Winter rye + vetch</td>
<td>Triticale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity in time</td>
<td>Winter rye</td>
<td>Maize</td>
<td>Winter rye</td>
<td>Triticale</td>
<td>Winter rye</td>
<td>Triticale</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Maize and grass-clover strip interactions show strong grass-clover competitive ability with 10-20% increased total dry matter production when grown in close proximity to maize (0-25 cm) as compared to >150 cm away. Total maize yield (silage) was increased from around 450 g dry matter per m² adjacent to the grass-clover strip up to 1000 g DM per m² when grown > 150 cm away ©hnie@risoe.dtu.dk

The grass-clover strip seems to be particularly competitive in the early growth stages reducing the annual crop yields significantly. Soil water content was reduced in the annual crops close to the grass-clover strip (0-25 cm), possibly due to efficient water use by the growing grass-clover reducing the annual seed emergence. Thus, when analyzing the final yields such initial growing conditions shaping the competitive ability of the annual strip needs to be taken into account. It is likely that changes in management practice could improve the annual growth. Another controlling parameter could be soil nitrogen, because increased clover proportion was found in the grass-clover strips grown adjacent to winter rye whereas an increased grass proportion was found when grown adjacent to vetch.

The first total crop biomass production during the two years will be presented together with initial conclusion on the interspecific competitive interactions between strips. Is it possible at this stage to identify advantages and possible drawbacks? And is the inclusion of a perennial grass-clover strip sufficient to enhance soil fertility, extract nutrients form deeper soil layers, fix N2 and compensate for the effect of annual crops on soil fertility?

References


Sorption refrigeration for milk-cooling to increase the profitability of farm-based biogas CHP

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This project has investigated from a technical and economic point of view the possibility of using heat from a dairy farm-based biogas CHP plant to cool milk using a sorption cooling technology. The latest technical developments in sorption cooling have been evaluated with respect to the cooling requirement for milk on the farm, and heat recovery technology for biogas CHP plants. A roadmap for future technical development of on-farm sorption cooling systems for milk has been established and the different possible pathways evaluated.

A model dairy farm for which a sorption cooling system is dimensioned, with 160 producing cows, a conventional milking system and a family residence of 150 m² was described. Yearly electricity and heating demand for the farm and residence were calculated according to Hörndahl (2007). In addition milk-cooling demand (energy and dimensioning power) was calculated and a biogas CHP plant (using only manure produced onsite) dimensioned and costed according to Edström, 2008.

In selecting an appropriate sorption cooling technology for the model farm’s cooling system, initial evaluation showed that current sorption cooling technologies (both absorption and adsorption) using water as a working medium do not have output at a sufficiently low temperature to achieve a milk temperature of under 3 oC (as required by current EU regulations for on-farm milk-cooling). Meanwhile, currently available sorption cooling systems with ammonia as working fluid are capable of achieving output temperatures down to at least –10 oC and therefore meet EU regulations for milk-cooling. However, conventional ammonia absorption systems require a generator temperature in excess of 200 oC and are therefore not suited to the heat output from a biogas CHP engine (around 90 oC). A further development of the standard ammonia absorption system proposed by SolarFrost AG (Kunze, 2008) shows that it is possible however to achieve a refrigeration temperature down to –10 oC with a firing temperature of only 90 oC. This novel system requires however further technical development.

In light of the initial evaluation, a sorption cooling system for milk for the model farm is proposed incorporating existing icebank technology (for compact energy storage), pre-cooling using well water and a SolarFrost ammonia absorption refrigeration system. To allow an economic comparison, a reference system incorporating pre-cooling with well water and direct evaporation vapour compression cooling technology (but no ice bank) was specified. Taking into account auxiliary electricity use for circulation pumps and fans for the sorption cooling system, it is estimated that electricity requirement is reduced by 73 % with the sorption cooling system. Preliminary life-cycle cost (LCC) calculation for the sorption cooling system yielded a milk cooling estimate of 21,8 SEK/ton milk cooled. In this calculation it is assumed that the cost of heat used for firing the sorption cooling system is equal to zero, i.e. costs for the biogas CHP plant are covered by otherwise generated income for the plant (electricity, space heating and hot water production). This is compared to the estimated LCC cost for milk cooling for the reference system at 23,6 SEK/ton milk cooled. Calculated according to this methodology, the sorption cooling system thus yields LCC reduction for milk cooling of 10 %.
Based on the assumption of a breakeven LCC for the sorption cooling system compared to the reference system, the sorption cooling system generates an estimated income of 178 SEK/MWh heat. These data are preliminary results and the project is continuing during summer 2009.

References


In the year 2008, the agricultural sector was responsible for almost 9% of the total Norwegian greenhouse gas emissions which amounts to 4.8 million tones CO$_2$-equiv (LMD, 2009). Compared with the emissions in 1990 this was 2% lower, but 0.5% higher than in 2004. The biggest agricultural sources are enteric fermentation (CH$_4$), contributing 44%, and “agricultural soils” (N$_2$O) contributing almost 46%. The contribution from manure management was 10%.

The two sources of methane, enteric fermentation, and manure management, emitted 104 kilo tones methane, and the division between these sources was 85% enteric fermentation, and 15% manure management. Biogas is one of the possibilities for reducing greenhouse gas emission from agriculture (Monteny et al. 2006).

The aim of this paper is to present a model for calculating the reduction of greenhouse gases including nitrous oxide from ammonia emission when introducing anaerobic digestion. The model constitutes of four sub models:
- transport,
- methane emission from stables and stores,
- nitrous oxide from stores and fields,
- ammonia emission

As most of the Norwegian farms are comparatively smaller in size, there exists a possibility of installing cooperative plants in order to make biogas profitable for agricultural farmers. Transport emissions are calculated from (a) average distance between farms and plant, (b) size of a truck, and (c) greenhouse emissions from the actual truck. This is calculated as LCI (emission from crude oil extraction, transport, refinery plant, and fuel consumption) (Rydh et al. 2002).

Methane is emitted from stables (gutters) and stores (Sommer et al. 2004). Methane is being calculated according to Olesen at al. (2004). these formulas are used to calculate emissions from gutters, and stores. When calculating emissions from stored manure one needs to differentiate between emissions during the summers and winters. The calculations are optimized so that the result is equal to the emissions given by the Statistics Norway (Hoem, 2006).

In the model one assumes that the gutters are emptied twice a day, and that the storage is emptied two times per year. Cows, sheep, and goats are assumed to grass 100 days per year, and therefore methane will not be produced from gutters or stores during these periods. When biogas is chosen the same formulas are used, but when cooperative plants are chosen, the storage period is reduced to 30 days, else the storage period is zero. One assumes that there is no methane emission from the treated manure.

Nitrous oxide can emit from stores and fields. Calculations from Statistics Norway (Hoem, 2006) are used, and reduction factors when biogas is chosen are according to IPCC. Nitrous oxide can also emit from fields. Normally the direct emission equals all nitrogen input, and will not be influenced biogas. There are two sources of indirect emission; run off and ammonia emission. It is assumed that run off will not differ when applying biogas treated slurry, but one has to calculate ammonia emissions.
Anaerobic degradation of organic matters will lead to increase ammonia content; If not then measures are taken such as spreading of the manure which leads to increase emissions. On the other hand emissions from storage of manure will be reduced according to the kind of storage.

LCI data of fossil fuels from GEMIS (2009) is used when biogas substitute fossil fuels. The main results from the model shows that methane emission from houses is not reduced when biogas alternative is chosen. This represents 0.76 % of total emission. Because of reduction of time for storage of manure, and also because of reduction of emission (methane and nitrous oxide) for the biogas alternative, the reduction was calculated to 88 %. Indirectly nitrous oxide emission from ammonia was reduced by 97 %. This could be explained by the reduced ammonia emission from storage (slurry will be stored in closed tanks after it has been treated in a biogas reactor). In total the reduction was calculated to 87 %. Reference emission represents 12 % of greenhouse gas emission from agricultural sector.

Energy from anaerobic fermentation of manure is evaluated to be greenhouse gas neutral. Therefore, when it substitute fossil energy, it reduce net outlet of carbon dioxide, but when biogas substitutes hydro electricity, there will not be an additional contribution from energy production. Although the average distance between the farms and the plant is three-doubled, the transportation outlet is still relatively small. When energy from biogas substitute fossil fuel, the contribution from the substitution will accounts for more than 50 % of the potential carbon dioxide reduction. The reduction will be a little higher when it substitutes petroleum. When this contribution is included in the emission from agricultural sector, the reduction can be 19 – 23 % if all agricultural waste is treated.

References


Possible beneficial effects of biomass for bioenergy crops – a mini review and some new hypotheses
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Debate about biomass for heat and/or power generation often revolves around the potential for greenhouse gas (GHG) emission mitigation versus the detrimental effects of growing the crops on biodiversity and landscape aesthetics. This mini review aims to highlight some of the possible beneficial effects of growing bioenergy crops, including other options than the most talked about miscanthus or salix/populus. To keep the text short, it explicitly does not deal with the issue of GHG emission mitigation by substituting non-renewable energy sources with a renewable source and omits all negative impacts that biomass crops may have, highlighting only possible benefits. This strong bias allows for more detailed examination of less common aspects and options concerning biomass production.

The review deals with six different topics:
- biodiversity; with a focus on the effects of resources made directly available by biomass crops and by accompanying changes in landscape structure and rotation times
- water and nutrient management; in the context of biomass production in shelterbelts or riparian buffer strips for non-point source pollution mitigation and flood peak mitigation
- phytoremediation; including brownfield recultivation and landfill leachate treatment
- farm diversification and agroforestry; introducing options for multi-use forestry in combination with other biomass crops and use of coppice woodlands in livestock keeping
- farm animal welfare; farmer experiences and ongoing research
- public amenity; examining the potential role of biomass crops for swine odor mitigation and other more unusual applications

It is concluded that, dependent on regulation and the production systems, large scale biomass for bioenergy production can have considerable positive effects in many areas and offers options for innovative farm management and nature conservation as well as interesting nonstandard applications. Bioenergy crops on organic farms look especially promising for biodiversity conservation.

References


Consequences of agro-biofuel production for greenhouse gas emissions

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²) National Environmental Research Institute, University of Aarhus, DK

Currently CO₂ from fossil fuel combustion accounts for 57% of the global greenhouse gas emissions, whereas the strong greenhouse gases nitrous oxide (N₂O) and methane (CH₄) contribute with 8% and 14%, respectively (IPCC, 2007). Agricultural activity is the dominant source of N₂O, which is mainly associated with the use of nitrogen based fertilizers in agricultural production. Replacing fossil fuel-derived energy by biomass-derived energy is commonly and with increasing emphasis proposed as a mean to mitigate the CO₂ emissions. However, a recent analysis of global emission data proposes that accelerated emissions of N₂O associated with the production of biomass for bio-fuel purposes will outweigh the avoided emissions of fossil fuel-derived CO₂ (Crutzen et al., 2008).

In the present study we examined the effects on N₂O and CH₄ emissions when residues from bio-energy production were recycled as fertilizer for a maize energy crop within an organic cropping system. Furthermore, we assessed sustainability in terms of greenhouse gasses for co-production of bio-ethanol and bio-gas from maize. This was compared to estimated greenhouse gas balances for rye and grass-clover as alternative raw materials.

The maize crop was sown on the 14th of May 2008 and on the same day two different bio-gas residues were applied as organic fertilizer via simulated injection. The residues were anaerobic digested cattle slurry+maize and anaerobic digested slurry+grass-clover. For comparison untreated cattle slurry was included in the experiment and all fertilizers were applied at a rate of 150 kg plant available N ha⁻¹. During the following two months emissions of N₂O and CH₄ were measured regularly using two-part static chambers. As observed in many other studies significant, but short-termed, emissions of CH₄ took place after the slurry-based fertilizers were applied. In contrast, elevated N₂O emission persisted for almost two months and quite often at very high rates. The cumulative N₂O emissions during the two months amounted to 895, 725, 583 and 46 mg N₂O-N m⁻² in the digested slurry+maize, digested slurry+grass-clover, untreated slurry and control treatments, respectively. Thus, in general more N₂O was emitted from anaerobic digested slurry as compared to untreated slurry and the N₂O emission factor varied between 3.6 and 5.7 % of the applied N. This is substantial higher than the 1%-loss proposed by IPCC for direct losses of N₂O from organic residues. The experiment is repeated in 2009 and the preliminary results support the results from 2008.

The maize biomass was used for co-production of bio-ethanol and bio-gas. A greenhouse gas balance was made in order to highlight how much the field emissions of N₂O accounted for in comparison to the fossil fuel-derived CO₂, which was avoided by producing the bio-fuels. Preliminary calculations show that the greenhouse gas benefit of growing maize for bio-energy production was reduced by up to 70% due to N₂O emissions after soil application of bio-gas residues. In some cases there were no greenhouse gas advantage of fertilizing the maize crop, because the extra crop yield, and thereby bio-fuel production, was offset by increased field emissions of N₂O. This greenhouse gas balance did not include fuels used by farm machinery and fuels used during the production of the bio-fuels, thus the net energy production was actually
lower than assumed in the calculation. The N₂O emissions may therefore counteract an even larger proportion of the actual avoided fossil CO₂.

The reason for the high N₂O emission after simulated injection of slurry-based fertilizers is partly that the fertilizers were applied before the maize crop was present to take up the nitrogen. Furthermore, injection of the liquid materials produced anaerobic zones in the soil with high availability of nitrogen and labile carbon compounds, which is favourable conditions for denitrification and thereby N₂O production. Finally, the maize was sown late in spring to ensure high soil temperatures, which also stimulates the microbial turnover of nitrogen. In comparison, a similar experiment was carried out in a winter rye crop in March to May 2009, where three factors were changed: 1) The crop was present when the materials were applied, 2) materials were applied on the soil surface simulating application by trail hoses and 3) soil temperatures were predominantly in the range 0 to 5 °C. The preliminary results show very low N₂O losses.

The greenhouse gas balance for co-production of bio-ethanol and bio-gas from unfertilized maize was compared to a rough balance for unfertilized rye and grass-clover as alternative raw materials. The N₂O emission during the cultivation of the three crops was estimated to be more or less similar if the emissions related to ploughing down of the N-rich grass-clover residues was taken into account. However, the annual whole crop yields were about 30-40% lower in rye and grass-clover as compared to maize and furthermore, the conversion of plant biomass into bio-ethanol and bio-gas was less efficient. All together the fossil CO₂ avoided by producing rye and grass-clover bio-fuels appeared to be less than half as compared to maize bio-fuels. Thus, based on these rough greenhouse gas balances rye and grass-clover did not seem to be better alternatives than maize. However, a more thorough investigation is needed when data becomes available.

To summarize, our study emphasizes the risk of large greenhouse gas emissions in relation to management of wastes from biogas plants, which may negate the potential global warming savings.

References

Synergies between the expansion of biogas production and organic farming

By Dalgaard T\(^1\), Haugaard H\(^2\), Jørgensen U\(^1\), Kjeldsen C\(^1\), Kristensen IT\(^1\) & Pugesgaard S\(^1\)

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Introduction and aim

In June 2009 The Danish Parliament passed a plan for Green Growth, including ambitious goals for the expansion of biogas production to include 50% of all animal manures by 2020, and an increase of the organic farmed area by 150% in the same period, thereby covering more than 15% of the total farmed area in 2020 (Ministry of Economic and Business Affairs Denmark, 2009).

The aim of this paper presentation is to review possible synergies between this expansion of biogas production and the development of organic farming. Especially, we will discuss the rural development perspectives, and the major barriers and problems for such development. This include a discussion of how this development can help to reduce greenhouse gas emissions, and as The Danish Rural Development Program is mentioned as the central policy program to support the Green Growth Plan, it is discussed how such reduction might be combined with new opportunities for rural development.

Materials and methods

Based on information from digital farm registers (Hauge Petersen et al. 2006) a national Geographical Information System including information about placement, land use, livestock production and fertilization practice for all Danish farms have been constructed (see www.djf-geodata.dk). In a number of ongoing Research Projects (see for example http://www.bioconcens.elr.dk, or http://liv-projektet.dk/, Danish Food Industry Agency 2009a) these data are used to assess effects of rural development measures implemented in Denmark, including the present investigation of the effect of expanded biogas production. Figure 1 shows an example of the livestock density mapped for the North-Western part of Denmark based on these data, and Table 1 shows a summary of the derived national figures regarding biogas production potentials.

![Livestock units per 5 km grid cell](image)

Figure 1. Example on the mapped livestock density in North-Western Denmark 2006. One Livestock Unit (LU) equals 100 kg Nitrogen from livestock manure ex store.
Table 1. Biogas potential summarized from all Danish livestock 2006. It is assumed that all slurry but no other manure sources are used for biogas production in the form of methane (CH₄). One Livestock Unit (LU) equals 100 kg Nitrogen from livestock manure ex store.

<table>
<thead>
<tr>
<th>Livestock Units</th>
<th>Slurry proportion</th>
<th>Biogas production per Livestock Unit</th>
<th>Total biogas production</th>
</tr>
</thead>
<tbody>
<tr>
<td>(10⁴ LU)</td>
<td>(% of manure)</td>
<td>(10⁰⁶ m³ CH₄/10³ LU)</td>
<td>(10⁰⁶ m³ CH₄)</td>
</tr>
<tr>
<td>Cattle</td>
<td>1,020</td>
<td>48%</td>
<td>0.361</td>
</tr>
<tr>
<td>Pigs</td>
<td>1,259</td>
<td>84%</td>
<td>0.281</td>
</tr>
<tr>
<td>Poultry/fur animals</td>
<td>106</td>
<td>25%</td>
<td>0.376</td>
</tr>
<tr>
<td>Others</td>
<td>15</td>
<td>8%</td>
<td>0.573</td>
</tr>
</tbody>
</table>

Preliminary results

The livestock intensive region of North-Western Denmark has been selected as a case study area (Figure 1), and the biogas production potentials for this region have been mapped (Figure 2).

![Figure 2](image)

Figure 2. Mapped potential biogas production from livestock manures in North-Western Denmark 2006. Hot spots with a large potential biogas production are the darkest colored areas.

Based on the methods presented in Nielsen and Hjorth-Gregersen (2002), Hjorth-Gregersen (2009), the socio-economic consequences of such large-scale implementation of biogas production will be assessed. From the hot spots shown in Figure 2 it is obvious that some rural areas have special possibilities biogas production, and it is interesting that these areas seem to overlap with the areas with special interests in rural development mapped by Kristensen et al. (2009).

Moreover, current research results show that especially in livestock intensive areas, the expansion of both organic and conventional farming is limited by the competition for land, but redistribution of manure via biogas plants can help to mitigate this barrier, and create special potentials for the development of more sustainable...
farming systems (ICROFS 2008, Dalgaard et al. 2008a, Kjeldsen et al., 2009). This is demonstrated via results from the ongoing research project on biomass and bioenergy production in organic agriculture (BIOCONCENS 2009), illustrating examples on the potentials for optimization of nutrient recycling and the reduction of greenhouse gas emissions (Pugesgaard et al., 2008).

Conclusions and perspectives
It is concluded, that the planned 150% increase in organic farm area is realistic and, in combination with bioenergy crop production for the biogas plants, it is even possible to make the organic farming sector independent of manure imports from conventional farming. This will contribute to the vision of a Danish Economy independent of fossil fuels by 2050 (The Danish Climate Commission 2009), and to the special needs defined in the Danish Rural Development Program (Danish Food Industry Agency 2009b), which in the Green Growth Plan is mentioned as the central policy program to support conversion to more biogas production and organic farming. The maps over the total biogas production potentials can be compared with maps over the potential conversion to organic farming in Denmark (see Kjeldsen et al. 2009). Thereby regional differences are illustrated, showing that the combined expansion of biogas and organic production has a special potential to support development in areas designated with a special need for rural development (Dalgaard et al. 2008b). Based on these results, included in ongoing Rural Development research (see for example http://www.bioconcens.elr.dk, or http://liv-projektet.dk), recommendations for future rural development programs, supporting the expansion of biogas production and organic farming, can be summarized.

References


Biomass Supply Chain Management in Denmark

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The raw materials for biomass conversion are produced over large geographical areas, have a limited availability window, and often are handled as very voluminous materials. As a result, the transportation and logistics between point of production and to the conversion facilities becomes a vital part of the overall operational, economic and energetic viability of the biomass conversion process. At present, however, producing energy at power plants from biomass is far more expensive than from other more traditional sources such as coal and gas, partly as a result of the logistics costs involved in fuel supply.

The biomass supply chain is made up of a range of activities which include harvesting, baling, storing, drying and transport of the biomass both on the field and to the biorefinery. The whole network operates in time and space coordinates so in order to estimate the logistics costs, a global view of the processes, which are strongly interlinked, is needed. Biomass from oilseed crops has two different products: the seeds and the straw, which need different care and processes, and most probably will have distinct destinations.

Supply chain management (SCM) involves coordinating and integrating activities and processes among different parties for the benefit of the entire supply chain. The integration of multiple functions in a global supply chain context is complex. Information technology systems have been recognized to facilitate the processes of supply chain management through integrated information sharing, process automation, and relationship management programs (Lancioni et. al 2003).

There are several harvesting procedures that depend on the special characteristics of the biomass being harvested. For example, if the biomass is wood, then bigger machineries may be needed. But when harvesting agricultural biomass, normal combine harvesters can be used, with minor modifications (i.e. heading of the cutter blades). Also, if the straw is the main biomass, rather than the seeds, then special attention for the baling operation implies use of extra machinery.

For handling the biomass there are pre established routines that take into consideration preserving the quality and the quantity during this operation. The handling operation should be taken into consideration during each step of the chain. The storage of biomass implies even more attention due to the limited availability of the biomass; given the fact that biomass is required all year round.

Denmark is situated in the northern part of EU and is one of the Nordic and Scandinavian countries. It is a small country with a population of 5.3 million inhabitants. Denmark is a flat country with rich agricultural land situated in a temperate climate. Of the 4,308,000 ha, which present the total area of Denmark, 62 percent (2,679,000 ha) are cultivated. Danish agriculture is characterized by a wide variety of activities, among which cereals are the most important production, accounting for almost 55% of the total area. The main crops in Denmark are cereals, rapeseed and sugar beet making up for more than 87% of the total plant production (excl. grass) (source: www.statbank.dk).
Denmark has long tradition of using agricultural biomass as a source of energy. Farmers are used to sell their bales to the nearby Combined Heating Plant (CHP) that provide heating and hot water for the community in which they operate, resulting in less transport distance for the farmers. Small CHPs usually have a contract with the farmers and the bales can either be brought with one shift or in turns during the whole year round. Thanks to the technological advances lower quality biomass can be used, so bales with moisture content higher than 25% can still be sold.

According to the Danish Ministry for Food, Agriculture and Fisheries report on bioenergy, December 2008, nearly 41% of grain straw and 15% of rape straw is being used for energy purposes. It is assumed that by the year 2020 the producing area of straw for the energy sector only will increase to 150,000ha.

The other main type of agricultural biomass are the seeds, among which, rapeseed is the most popular crop in Denmark. Oilseed rape is grown in Denmark on 179,200ha in 2007. Due to the rotational characteristic of the crop, the maximum agricultural area that can be used is 20% (around 530,000 ha) of the total Danish agricultural area (www.statbank.dk). Winter rape has been grown in Denmark for many years with good results. The average yield of rapeseed is 3.5 tones (between 3.8 – 4.5 tones of seeds; it is also common to have 5 tones yield every six years), (A. Kristensen, personal communication).

There are two end-products from rapeseed and these are biofuels, and oil for industrial or human consumption. In either case, the production takes place on an industrial scale, having more centralized facilities and an increased amount of raw materials. Thus, the supply chain of rapeseed implies higher distances to be traveled and this represents a disadvantage both for the farmers and the companies involved.

One of the main reasons that biomass has lower energy efficiency than other fuel sources is because the net outcome of the process is strongly influenced by the expenses of pre-processing and conversion techniques. Optimizing the pre-processing steps will therefore provide a better insight of what problems must be attended first or which need more attention from the research point of view.

References
Start-up of semi-continuously operated and completely stirred dry fermentation pilot-scale biogas reactor

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Biogas technologies meet the requirements of renewable energy production, reduced greenhouse gas emissions and production of organic fertilisers and soil conditioners. Biogas is produced during anaerobic digestion of organic matters. Methane included in biogas can be used for electricity and heat production on-site, in natural gas network or as traffic fuel. A farm can be self-supporting in heating energy and electricity and it can also produce energy for selling. Digestate contains all the nutrients present in raw material. Therefore, biogas technologies recover nutrients and carbon, and clearly reduce the smell of the manure and destroy pathogens and seeds of plants.

Most of the dry fermentation biogas plants in Europe are operated as a batch without any stirring. In Finland, there are only ten farm-scale biogas plants, and all of which are handling liquid slurry. However, there are several farms that are interested in dry manure system. The cold winter conditions in Finland set challenges to the technology.

In the year 2008, MTT Agrifood Research Finland built a pilot scale biogas reactor of 4.5 cubic meters situated in Sotkamo research station. The aim is to develop a completely stirred and semi-continuously operated biogas reactor that handles solid biomass. Also, working as a tool for development, the project disseminates information of the benefits of the biogas utilization. The project was funded by MTT and European Agricultural Fund for Rural Development (EAFRD).

The biogas reactor was built of (usual) steel. Only the gas tube is stainless steel. The reactor is situated in a half-warm space and the input silo is in a cold space. It is possible to heat the digester, the input silo and the repulsive tube. The content is stirred by a roller conveyer. The only input was solid manure with peat and straw litter. Later also field biomass and waste from fish cleaning will be added.

At the start, the reactor was filled by 3 m3 of solid manure and operated as a batch. No seed material was used. After six days biogas production increased rapidly and was as its highest during the 15th-21st day. Overall biogas production from 3 m3 of solid manure was nearly 80 m3 biogas during six weeks.

The continuous run was started right after the start-up run with an organic loading rate of 1 kg of volatile solids (VS)/m3d. The reactor was stirred 30 min per time twice a day. The reactor was fed and stirred five days a week. During the first three months the biogas production was steady, between 0.6-0.8 m3/d. The methane content of the biogas was 54-59 %. The overall methane gain was 25 m3/tn manure. During the process, the material transformed from solid to almost liquid. While the total solids (TS) of the input was 15-23 %, the TS of the residue was only 10-15 %.
Development of Anaerobic Digestion Control and Automation with pilots in Estonia

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Anaerobic digestion is widely used for waste treatment, manure stabilization and also bio energy production. Anaerobic technology is studied for long period but there is still problems with process control due to lack of information as there is no cost efficient reliable on-line sensors. Improvements of biogas production have been shown to be possible with advanced process control, using proper sensors and control algorithms.

Main targets are generally:
- normally stable operation;
- maximization of energy production;
- avoid damage to, or inhibition of the reactor sludge;
- etc

Pilot scale unit built in Estonia including 3 digesters and equipped all necessary devices to do research on anaerobic digestion:
- sensors: temperature, pressure, liquid and gas flow, pH, level;
- on-line analyzers: gas composition, VFA, bicarbonates, alkalinity;
- universal controller: data acquisition and close loop control;
- improved SCADA system: visualization, web access, control models.

This facility is open for cooperation. More info about workgroup is available: www.emu-bioconversion.eu
Pilot scale application of thermophilic and extreme thermophilic pre-treatment for biogas production, 
by Alastair James Ward

Biogas potential from different meadow grasses, by Chitra Sangaraju Raju

Can use of biogas production help to improve nitrogen management in organic cropping systems? By Michal Adam Brozyna
All year supply of willow biomass to power plant

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Harvest of willow is performed in the period from November until March when the moisture content in the crop is relatively low. However, a power plant runs all the year round and will therefore need supply all the year round. To fulfill this need of biomass supply different harvest and handling chains on willow can be used.

Elements in the handling chain.

Today willow is typically harvested either with a modified chipper, CLAAS or similar (combined harvest and chipping), or with a whole shoot harvesters, NB STEMSTER or similar, followed by chipping with conventional forest chippers.

Using the current machines and methods, combined harvest and chipping is cheaper than whole shoot harvest and post-harvest chipping (Styles et al 2008). However, whole shoot harvest have advantages in terms of a flexible harvest and supply chain (Kofman et al., 1997) and possibilities for low cost drying (natural wind drying) and thereby an improved fuel quality (Harders, 2002).

It is necessary to establish storage piles of willow in order to supply fuel outside the harvest period. At harvest the moisture content typically will be 50-60%, and storage of that moist material will cause loss of dry matter and risk of growth of both bacteria and fungi. Piles of fine chips can be so infected that they will cause a health risk during handling.

Storage trials shows that the losses are influenced by the sizes of the material, thus the lowest loss is seen in whole stems and the biggest loss is seen in fine chopped chips. Storage for 5 month may result in 3 – 20 % loss (Kofman et al., 1997). Airtight or anaerobia storage of willow chips by the method known from silage is possible. The storage loss by this method is only 10-12 % when stored for a 9 month period (Landbrugets Rådgivningscenter et al., 1997). Airtight storage prevents the growth of bacteria and fungi, thus ensuring a better environment for the people working with the handling of the material.
The density of the biomass is crucial for the transport costs. The costs increase when the density decreases. The density of 20 cm chunk is about 90 kg/m³, whereas it is about 150 kg/m³ for 2-5 cm chips.

In order to evaluate different options for willow harvest and supply chains a modelling tool is need. The supply chain must comprise optimized steps of harvesting the crop, collecting, storing and transporting to power plant (Sambra et al., 2008). The model must include type and duration of storage and the resulting dry matter losses as well as fuel characteristics.

References


Landbrugets Rådgivningscenter, Elsamprojekt, Forskningscenter for Skov og Landskab (1997). All-year Handling Chains on Short Rotation Forestry (Willow) for Power and Heat Conversion (Gasification), Elsamprojekt


Producing bio-energy is one of the focus of the agriculture and using biomass of different crops as renewable resource are more and more realistic eco-friendly energy resource. The selection of appropriate plant species is an important aspect.

One of the ways is to use traditional crops for example grasses for energy purposes. Now when cattle-breeding is decreased extremely it is time to look for alternative use of grasses. The present study was designed to determine the contents of substances determining tall fescue (Festuca arundinacea Schreb.) and cocksfoot (Dactylis glomerata L.) biomass energy value and yield in relation to cutting timing at heading and flowering stages as well as the impact of tall fescue fertilisation on its chemical composition and yield per one year's cycle of use. Preliminary research results suggest that the time of the first cut can influence annual biomass yield and quality and it is better to harvest cocksfoot and tall fescue for biogas production at heading stage when there was indicated less lignin, more water-soluble carbohydrates and better carbon to nitrogen ratio compared to flowering stage.

Whereas plants for energy purpose should have high yields and low production inputs, could be attractive some alternative crops. Herbaceous plant species like Miscanthus giganteus, Sida hermaphrodita, Silphium perfoliatum, Artemisia vulgaris, Artemisia codonocephala were investigated during first two years. Biomass yield data during first two years showed that quite productive was Sida hermaphrodita comparing with Dactylis glomerata, however the other crops were less productive. Futher research on grasses and alternative crops management is needed.
Straw as bioenergy in Norway

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In Norway straw is used for animal bedding, feed and an increasing amount is used for heat production. Otherwise the straw is returned to the soil by ploughing or harrowing or in some cases it is burnt on the soil surface. Very little information is available on the total amount of straw that is available for heating.

In a project started in 2008 we aim to calculate the total resources of straw in Norway, and how much of this that can be used for heating, taking into consideration the need for other purposes and the effect of removal of straw on soil quality parameters such as structure and content of carbon and potassium. Straw yields are measured in the cereal production areas of Norway in field trials using the most common varieties of spring barley, oats and wheat.

Preliminary calculations indicate that straw can be an important source of energy also in Norway, and the first years’ yield results indicate that the straw yields are higher than earlier calculated.
Miscanthus as fuel in small combustion plants

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Among the different biomass materials the perennial grass Miscanthus Giganteus present some valuable advantages such as low input crop, relative simple cultivation and harvest, high yield potential and the handling and storage of the biomass can be done with well known and existing methods used for straw.

Investigations have been made in Denmark regarding combustion of Miscanthus Giganteus in farm heating boilers designed for straw. At the combustion laboratory at Research Centre Bygholm, full scale tests have been made. The tests have been made based on methods stated in standards (EN 303-5, 1999 and PrEN 303-5, 1995). The combustion qualities are described by means of fuel analyses and measurements of boiler efficiencies and emissions.

Fuel analyses

Thermal value, ash content, volatile components, melting progress of ash etc. are given in Table 1. For comparison the results from equivalent analyses of wheat straw are given. The Miscanthus were harvested in spring (so called delayed harvest).

<table>
<thead>
<tr>
<th></th>
<th>Thermal value (upper)</th>
<th>Ashes</th>
<th>Volatile components</th>
<th>Sulphur</th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Nitrogen</th>
<th>Melting progress of ashes, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(effective)</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>Softening temp.</td>
</tr>
<tr>
<td>Misc.</td>
<td>17.1/15.8</td>
<td>2.6</td>
<td>69.7</td>
<td>0.11</td>
<td>41.5</td>
<td>5.4</td>
<td>0.5</td>
<td>1020</td>
</tr>
<tr>
<td>Straw</td>
<td>18.4/15.2</td>
<td>4.0</td>
<td>70.0</td>
<td>0.16</td>
<td>42.0</td>
<td>5.0</td>
<td>0.4</td>
<td>950</td>
</tr>
</tbody>
</table>

The effective thermal value of straw from grain is 14-17 MJ/kg. The thermal value of Miscanthus Giganteus is the same as that of straw. High softening, hemispherical and flow temperatures are considered to be advantageous, but the differences measured are small. In general, the ash and the sulphur contents are lower in Miscanthus Giganteus than for straw from grain, but apart from this, no considerable differences were found.

Combustion tests

The following boilers were used for the combustion tests: Pilevang batch stoker for big bales, type PM 330, and Aunslev automatic stoker, type 6B - 150, with fluffer, type 120.

The big bale batch stoker was used for combustion of big baled Miscanthus. The boiler had a horizontal, cylindrical combustion chamber. An automatic fan was used to deliver the combustion air. Combustion air was automatically regulated in proportion to the smoke temperature.

An efficiency of about 80% was obtained. That is 0-5 pct. points more than what could be obtained during combustion of wheat straw in the same boiler. The average emission of solids was 240 mg/normal m3 of flue gas at an oxygen content of 10%. During the combustion of wheat straw, the average emission of solids in the boiler...
was 550 mg/normal m³ of flue gas at an oxygen content of 10%. A very low CO content (around 0.1%) was generally found.

The stoker boiler with fluffer system was used for combustion of big bales of both chopped and un-chopped Miscanthus, and for combustion of loose chopped Miscanthus. After an adjustment of the fluffer drum it became possible to tear un-chopped Miscanthus bales apart. However, the subsequent air transport caused many stoppages due to blockage of the material in the fan and in the pipes. This caused a somewhat uneven dosage. At an average stoking rate of 32 kg/h an efficiency of 74% was obtained. The average emission of solids was 640 mg/normal m³ of flue gas at an oxygen content of 10%. There was a great and highly varying CO content in the smoke (0.1 - 1.0%). The same rates of efficiency and emission of solids were obtained in the boiler as was obtained for combustion of straw from grain.

The composition of the ashes can be a problem when burning solid biofuels due to relative high potassium content. Slagging and fouling reduce heat transfer and may cause corrosion problems (Collura 2006). For this Miscanthus combustion tests an approximate bottom ash content of 2.5% was found. This was somewhat lower than for combustion of straw. No problems with slagging and fouling were observed and the ashes consisted of a fine, grey powder without hard clinkers. However, combustion test with Miscanthus pellets in boilers designed for sawdust pellets caused lots of problems with formation of hard slag (Teknologisk Institut 1999).

References


Biomass of maize and hemp from different growth phons.
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In 2008/2009 the productivity of maize and hemp cultivars influenced by different N treatments (natural, mineral fertilizer, vetch, slurry and wastewater sludge) was investigated. The amount of N from different resources was 100 kg N ha-1. Aims for current research work were (i) to find out the species and the species mixtures, which could be cultivated in Estonian conditions for the energy biomass production; (ii) to find out the best nitrogen resource for maize and hemp above ground biomass formation.

The field crops productivity was studied in a case of pure and mixture sowings, the biomass chemical composition including heavy metals was measured. The moisture content of hemp cultivars’ above ground biomass were observed during winter period.

Preliminary results.
The highest above ground biomass yield was obtained from treatments fertilized with wastewater sludge (for maize 11.1 and for hemp 7.5 t DM ha-1; in N0 treatment 4.8 and 4.1 t DM ha-1, respectively). The wastewater sludge utilization in Estonian weather conditions could be possible for species which active growth occurs during second part of summer (like maize or hemp in this area). The sowing rate of silo maize (8 plants per m2) was used, but to minimize outgoings the herbicides were not used. Therefore the percentage of maize in above ground biomass was over 50% only in treatments fertilized with sludge and slurry, in other treatments the weeds formed the major part of above ground biomass. Hemp cultivars suppressed weeds very well and the percentage of hemp in above ground biomass was 95–100%. The above ground biomasses of maize + vetch mixes and hemp + vetch mixes were statistically equal to control treatment N0. The biological nitrogen bound by Rhizobaceae probably is not available for other plants in the first vegetation period, or the sowing rate of vetch was too high and competition between plants results in low above ground biomass.

In consequence of heavy wind and snow the hemp plants were lodged and snow-capped by March 2009. Therefore in spring the harvesting of hemp plants with combain was impossible. The last harvest time for hemp was in November, when plants obtained DM content 82% and plants still standed well. DM content of plants influxed mostly by environmental conditions and it is difficult to determine the firm, exact time for harvesting.

Hemp is a plant which phytoextracts heavy metals. On the basis of heavy metals analysis in hemp plants it was ascertained that fertilizing with wastewater sludge caused the increase of Cr, Cu, Ni, Pb, and Zn 1.5, 1.2, 2.3 and 1.3 times, respectively in hemp plants comparing with plants grown in N0 treatment.

The yield of energy was calculated: the yield of energy from hemp plants grown on wastewater sludge and N0 treatments was 35.4 MWh ha-1 and 19.35 MWh ha-1, respectively. The content of heavy metals in sludge was low and the using of this sludge as fertilizer is possible again in next year.
Session IV – Technology

On-line measuring equipment for bio-gas
Dipl.-Ing. Axel Kühnert from Messtechnik EHEIM GmbH, info@messtechnik-eheim.de and Hans Peter Hansen from ScanTronic ApS, hph@Scan-Tronic.dk

First of all we will in the list of lectures of the session and under the headline: On-line measuring on a biogas plant - what can be achieved? present a row of examples of how we on bio-gas plants using on-line measuring equipment have revealed errors, set light on bad procedures and pointed out plant design that could be improved.

But we also look forward to receive you individually at our poster stand where we will be present with our equipment, answer questions and demonstrate the facilities. Based on experience since 2002 gathered on biogas plants Messtechnik EHEIM GmbH offer efficient equipment for mobile and stationary analyse of biogas and gas-quality.

VISIT 03 VISIT 04 (semi-stationary with gas-selector or stationary)

And, as the lecture will tell you, the use of diagnose systems has in the elapsed 7 years proven their value.

The product range consist of portable suitcase based units for fast operation, rack mounted moveable units for longer use and wall mounted units for continuous use. This is again supplemented with the the unique WinData program for visualisation and recording and other PC-based tools.

The equipment cannot “regulate” the problems away but when used as a tool it can - in a combination of diagnose and therapy often reveal/solve the problems in only one service visit.

The saved costs for extra driving expenses, individual reminiscence on return, preparing of datamaterial for discussi-on, shipping of diagnose documentation,
return discussion with lo-cal personnel as well as speculation of possible therapy tasks can pay for the equipment in only 2 or 3 operations.
Combustion of the fiber fraction from separated slurry

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In Danish livestock production solid-liquid separation of animal manure are being a more and more used technology. Manure separation can contribute to reduce nutrient leaching from farm land by facilitating better distribution of the nutrients (Kristensen et al., 2009 and Moller et al., 2007). Separation produce a liquid fraction containing soluble components such as nitrogen and potassium and a soiled fraction (fiber fraction) containing the majority of the organic matter and a great part of the phosphorus (Jørgensen et al., 2009)

In areas with high density of animal production there will be a surplus of phosphorus if using al the manure as fertilizer for the locale crop production. The manure as well as the solid fraction is very voluminous, and therefore it is expensive to export the product to other areas. In such cases combustion can be a way to produce energy and at the same time ashes with high content phosphorus easy to transport to areas with phosphorus deficit.

The aim of this research was to test and evaluate co-combustion of the solid fraction, - the fibre fraction - from pig manure and straw in a 200 kW biomass boiler designed for wood chips or chopped straw. Focus has been on mix proportion (how high percentages of the fuel can manure fibre), energy production and emissions.

Tree different types of manure fibre fractions were used. The dry matter content in the fibre fraction was from 23 to 35 percent and ash content fro 15 to 35 percent. The highest dry matter and ash percentages were found in biologically treated manure (anaerobic digestion). Wheat straw was used as reference fuel.

Some results from the combustion tests are shown in the table 1 (Kristensen et al., 2009).

Table 1. Co-combustion performance of pig slurry fibre fraction and straw.

<table>
<thead>
<tr>
<th>Fuel, % on weight base</th>
<th>Energy output, KW</th>
<th>Boiler efficiency, %</th>
<th>CO in flue gas, ppm</th>
<th>NOx in flue gas, ppm</th>
<th>Dust emission mg/m3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>From manure fibre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54% Fibre no 1 + 46% straw</td>
<td>207</td>
<td>22</td>
<td>-</td>
<td>1145</td>
<td>-</td>
</tr>
<tr>
<td>55% Fibre no 2 + 45% straw</td>
<td>228</td>
<td>40</td>
<td>80</td>
<td>959</td>
<td>345</td>
</tr>
<tr>
<td>38% Fibre no 3 + 62% straw</td>
<td>231</td>
<td>18</td>
<td>77</td>
<td>1279</td>
<td>346</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>246</td>
<td>0</td>
<td>78</td>
<td>473</td>
<td>432</td>
</tr>
</tbody>
</table>

To obtain a good combustion the maximum amount of fibre fraction was the stated values in table 1. The majority of the energy output comes from the straw and only 8-18% comes from the slurry fibre. It was possible to obtain a boiler efficiency of about 80% during co-combustion, the same efficiency as when using only straw.

When co-firing the level and the variation in CO content in the flue gas was higher than when using straw. This was due to a more stable and constant combustion progress for straw.
The emission of solid particles (dust) was very high when slurry fibre was a part of the fuel. This can be explained by the high ash content in the fibre fraction. The emission was unacceptable high and the plant must be provided with some kind technique for cleaning the smoke.

In general the NOx emission was not increased by adding slurry fibre to the fuel despite the fibre contain much more N than the wheat straw. From literature it is known that higher fuel-N and higher temperature increase formation of NOx (Zhu et al., 2004 and Lundgren et al., 2009). It was seen that when adding small amounts of fibre, 0 up to 20%, the NOx as expected was increasing in proportion to the fibre percentage, but for higher amount of fibre a decrease in NOx emission was seen. This decrease could be explained by the fact that the combustion temperature decreased at high amount of slurry fibre in the fuel.

References


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Technologies and machinery for energy crop harvesting, by Peter Storegaard Nielsen
Session V – System approach

Potential for oil production based on alternative oil seed crops in Norway

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For various reasons the area suitable for growing rape (Brassica napus L. var. oleifera Metzg.) and turnip rape (Brassica rapa L. var. oleifera Sinsk.) is limited in Norway. There are several other oil producing species, both cruciferous plants and others, but only a few of them have previously been investigated under Nordic climatic conditions.

As a part of a project called “Opportunities for Norwegian production of bio-diesel from agricultural crops” some alternative oil seed crops were grown on three sites in the years 2007 and 2008. The sites were Apelsvoll and Vollebekk in South-Eastern Norway and Kvithamar in the Central part of Norway. The following species were investigated: Oil flax (Linum usitatissimum L.), Sunflower (Helianthus annuus L.), Sarepta mustard (Brassica juncea L.), Camelina (Camelina sativa L.), Crambe (Crambe abyssinica Hochst.) and Blue lupine (Lupinus angustifolius L.). Also a cultivar of spring rape was included in the experiments. In the first year the oil seed yield was rather low for all crops on all sites.

In 2008 the quality of the experiments was better, and particularly at Vollebekk and Kvithamar the yields were satisfactory. However, for sunflower the growing season was too short at the experimental sites, and for camelina, crambe and sarepta mustard the seed yields were rather low. Oil flax and spring rape produced about 2.4 tons oil seeds per hectare and for blue lupine the yield was about 3.7 tons of seeds. In addition to seed yields, data on oil contents of the seeds will be presented.
Biomass supply chain management involves coordinating and integrating activities and processes among different parties for the benefit of the entire supply chain. The integration of multiple functions in a global supply chain context is complex. Information technology (IT) systems have been recognized to facilitate the processes of supply chain management through integrated information sharing, process automation, and relationship management programs. The increasing use of Internet in a business-to-business context has further improved the supply chains through real time collaboration, 24/7 availability and access to worldwide markets (Lancioni et al. 2003), a very important aspect for obtaining a successful supply chain.

The use of available IT technologies aims at improving the entire biomass supply chain by information sharing between participants and avoiding bottlenecks.

Sharing of information can obviously be a problem since the companies involved in the supply chain may not be prepared to share their production data, especially when those companies are independent of each other (Terzi et al. 2004). Appropriate business processes are a prerequisite for the strategic utilization of information to assure everybody involved benefits the information (Trkman et al. 2005). Additionally, human factors have to be considered, decision-makers at various points in the supply chain are usually not making optimal decisions (due to the lack of information, company strategy or their personal hindrances) (Trkman et al. 2005).

Real time information helps the participants to cope with changes of uncontrollable external factors affecting demand (e.g. prices, lack of resources, production halt, etc.) through real time measurement of demand.

Given the unforeseeable character of the factors influencing the supply chain of biomass and the large number of human factors involved in this process it can be rather difficult to state which is the optimum chain. Also, companies tend to optimize their own performances disregarding the supply chain as a whole, resulting in a local optimization instead of global. All this knowledge should be included in a system that can answer all the important aspects of logistics of biomass.

This study intends to describe the architecture for a common database aimed at all Supply Chain participants, by outlining all the information needed for each stakeholder to be satisfied with its outcomes.

Ideally, each user will have its own profile, so that each time they access the database there is no need to introduce again the same inputs like location, available technology, etc. Also by logging into the system, new changes in the area that concerns them will be shown. Using this tool will help the participants to the biomass supply chain stay informed on all the changes regarding the entire aspect of the process, make better evaluation, organize and plan more efficiently their activities.

All the technology for making such a tool already exists, and is available on the market. With the help of Personal Computers networked through the Internet, the information can be transferred using satellite systems or cables, making the database available anytime and anywhere. This will allow the communication between partners to be continuous and up-to-date by sharing the knowledge.
References
Potential of straw as bio-energy raw material in northern European countries

Katri Pahkala and Markku Kontturi, MTT Agrifood Research Finland, Plant Production, FI-31600 Jokioinen. Telephone: +358 3 4188 2460, fax: +358 3 4188 2437

Straw is a by-product of commercial field crops such as cereals, oilseeds (turnip rape, oilseed rape, linseed) and pulses (peas, faba beans). Seed yield of these crops is harvested by threshing when the straw material is left on field surface in swaths. In Denmark, straw is used for energy in large scale (1 million t/a), but in many other countries only a minor part of cereal straw yield is utilised: for example in Finland 20% for animal bedding in pig and cow-houses, and about 6 million kg (2400 ha) for energy (MMM 2004). The rest is chopped and mulched into soil. There is very little information about commercial use of residues from oilseeds, linseed or other combine harvested crops. Data for harvested seed yield is given for the most important species in public statistics such as Eurostat, FAOSTAT and national statistics, but there is no statistics for straw yields from practical fields.

In this study, the current bioenergy potential of straw yield was estimated for North European countries (Denmark, Estonia, Finland, Latvia, Lithuania, Norway and Sweden) by using information about seed yield, seed dry matter (DM) content, harvest index and harvest losses. Harvest index (proportion of seed yield of total biomass in dry matter), was studied separately for each species. Harvest losses due to stubble height were studied from 11 crops in field trials in Jokioinen, Finland. The straw potential and energy values were estimated in TWh for each crop and country.

Stubble height of 15-20 cm left 20 to 45% of straw DM to field depending on straw height. Losses originating from harvesting and baling can be comparable to those in haymaking. The highest straw potential from oilseed crops and cereals was in Denmark (more than 10 million tonnes DM, 51 TWh).

In the future, there is straw available for energy use. However, agricultural residues play an important role in controlling erosion and maintaining soil carbon, nutrients, and soil physical properties. Quantities of removable residues depend on crop rotation, field management practices within rotation (direct drill vs. ploughing) and climate.
Analysis of local biomass resources for ethanol production
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Availability of biomass is a crucial factor in production of bioenergy, and analysis of available biomass resources is a key step when planning a large scale production of bioenergy. Here we present an approach for exploring possible biomass resources when planning large scale production of bioenergy based on plant biomass.

The methodology was developed in a case study concerning the 2nd generation ethanol demonstration plant BornBioFuel on the Danish island Bornholm. The ethanol plant is expected to produce ethanol and byproducts based on annually 40,000 tons biomass (dry matter) including various types of lignocelluloses. The location of the plant on an island brings along limitations in the biomass supply since shipping of lignocellulosic biomass to the island may not be feasible. Consequently, the biomass must be supplied by local sources on the island.

Analysis of the local biomass resources included three main parts.
1) Initial analysis of potential biomass resources. This included listing of all potential biomass resources and rough estimates of the quantities. The primary criterion for selection of resources for this project was that the biomass should either be unutilized or be categorized as waste. The use of energy crops as a biomass source was, however, also considered. The initial analysis included considerations of the timing of the supply, moisture content, handling, transport and logistics of various biomasses.
2) Experimental work with measurements of biomass quantity and quality. Based on the initial analysis, certain types of biomass were chosen for further investigation including field work to quantify biomass resources and laboratory work to evaluate potential ethanol yield of the biomass. In this project, field trials were carried out to measure yields of various grass species, catch crops, maize cultivars, and alfalfa at various cutting times. Also, grass production was measured on road sides with different types of vegetation and on airport areas. The experimental work provided a more qualified estimate of biomass resources and biomass quality.
3) Calculation of crop rotation scenarios for increased output of biomass for energy production. To further explore possibilities of extracting biomass from agricultural production, various crop rotation scenarios were constructed and compared to present systems. Specific scenarios were made for farms with predominant pig production, dairy production, and plant production respectively, to take into account that these farm categories have different requirements for fodder production. Scenarios with energy crops comprised inclusion of maize, grass or alfalfa as a replacement of e.g. wheat and oil seed rape in the present production. For each scenario, the overall production of various types of biomass was calculated, and a break-even price was calculated for energy crops when replacing other crops. To analyze soil effects and environmental effects of changing cropping system, soil carbon balances were calculated with removal of different proportions of straw, and potential nitrate leaching was estimated.

Altogether, the three parts of the analysis provides valuable information in the planning of the biomass supply of the ethanol plant. The method could be adapted to planning of other bioenergy projects relying on biomass supply.
Combined energy and feed production by thermophilic digestion of grass, maize and cattle manure

S. Falconi, C.S. Raju, H. B. Møller and A. Ward, Institute of Agricultural Engineering, University of Aarhus, Research Center Foulum, Denmark.

Anaerobic digestion is a well-known technology for biogas production from manure and crops. In organic farming there is an increased interest in producing renewable energy and at the same time there is a urgent need for production of high quality protein feed and organic fertilizers. Anaerobic digestion might serve all these objectives. By anaerobic digestion of crops and manure it is possible to produce energy and the digestate might be used for producing high quality protein feed and organic fertilizer. It has been shown in another study that the content of amino acids increase by 230% and lysine by 300% after biogas production from grass clover pasture (Gunnarson and Stuckley, 1986), making it a high quality pig feed in terms of protein quality.

In this study clover grass and maize have been digested in 130 l pilot digesters and cattle manure has been digested in 10 m³ research digesters. During the experiments several parameters has been monitored like biogas production, methane content, process state indicators (VFA, pH, alkalinity), and the total energy production and energy balance for the cropping system will be calculated.

The effect of the digestion on the amino acid composition will be monitored and the quality of the digestate as fertilizer will be assessed.

Figure: A crop to energy, feed and fertilizer process

References
Decision making tool for rapeseed crop
Ana Sambra, Claus Grøn Sørensen, Erik Fløjgaard Kristensen, University of Aarhus, Faculty of Agricultural Sciences, Dept. of Agricultural Engineering, Blichers Alle 20, DK-8830 Tjele, Denmark, tel: +45 8999 1900, Ana.Sambra@agrsci.dk

The development and implementation of improved growing systems, for the purpose of biomass production for biorefinery utilization, is gaining attention due to the increasing demands for biofuels and a variety of biorefinery products. Rapeseed is the optimum oilseed crop for Denmark in terms of yield, and its production increased over the past eight years from 81.000ha to 172.000ha in 2008 (source: www.statbank.dk).

Rapeseed is a rotational crop, and is usually included in a four years rotation with barley, wheat and oat. Therefore rapeseed production can increase to about four times the area at present, thus increasing the available quantity of biomass, both for rapeseed and rape straw. A decision making tool, oriented on the farm operations, can help increase the sustainability of growing such biomass crops in a more efficient manner.

Farm operations in a rotational crop production means that every year different machinery and time planning is needed. Having such a tool will provide the farmer better and real-time knowledge on the current situation of all his crops, giving him the possibility to plan his farm operations in a customized way. Depending on his machinery, field size and shape, crop, weather and time window, the farmer will be able to choose which operation should be done first in order to reach the desired results.
Capturing the potential of BlueGreen energy is a key contribution to attaining the EU’s 20/20 renewable energy target. Currently this EU-wide target is being translated into national targets, some of which, e.g. in Denmark, have been set even higher. This policy commitment is essential to overcoming the obstacles to renewable energy.

New energy sources can profit from established business models. The Enercoast strategy is one of applying proven supply chain management methodology and tools to the underdeveloped bioenergy market in a North Sea Regional context. The project's focus is clearly set on a defined range of regional bioenergy market initiatives and their transformation into sustainable value chains.

Supply Chain Management features an integrative approach to dealing with the planning and control of the material flows from suppliers to end-users, linking flows from raw material supply to final delivery. Such is the scope of the project.

The project will develop cooperation on the supply chains between
- University of Oldenburg (Project lead Partner),
- Ryfylke kommunan, Hjelmeland, Norway,
- Innovatum Technology Park, Trollhättan, Sweden,
- Northumberland College, Ashington, England and
- CBMI, Innovation Centre for Bioenergy and Environmental Technology, Tjele, Denmark.

The Danish part of the project will analyse the sustainability of the well established Supply Chains specific for the Danish case, i.e.
- Common farmer-owned Biogas plants and
- Straw, municipal waste, woodchips and other biomasses for Combined Heat and Power production (CHP) for District Heating

Business Contact
We are interested in contact with and create contact between all steps in the value chains from
- Producers of bioenergy (Farmers, foresters, municipalities),
- Users of Biomass (biogas, Combined Heat and Power production, other technologies),
- Conversion business,
- Energy users and
- Recycling companies

The Danish part of the project is co-financed by EU Interreg IVB North Sea Regional Programme, Central Denmark Region and the participating Randers, Norddjurs and Syddjurs municipalities.
Energy and land use efficiency of reed canary grass (Phalaris arundinacea L.) depending on nitrogen fertilisation

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The interest of increasing the share of alternative energy resources has been in focus during last decades. Studies have estimated potential bioenergy cultures suitable for given pedoclimatic conditions. In northern Europe reed canary grass is a promising bioenergy crop (Lewandowski et al., 2003). Increased interest of bioenergy production has forced scientific research to estimate plantation bioenergy potential.

The aim of present study was to describe the energy and land use efficiencies in growing reed canary grass as energy crop. Field experiment with reed canary grass was performed in 1968–1976 in Estonia (Olustvere, N 58°33′, E 25°33′) (Rand, Krall, 1978). Reed canary grass variety ‘Jõgeva 1′ was sown in Haplic Albeluvisol with sandy loam texture (soil Corg 12 g kg⁻¹, Ntot 1.2 g kg⁻¹). The N fertiliser doses applied annually were 0, 120, 240 and 360 kg ha⁻¹. Additionally for all N fertiliser variants 35 kg P ha⁻¹ and 133 kg K ha⁻¹ were annually applied. Aboveground biomass was harvested and measured in autumn.

For estimating production energy and land use efficiencies it was considered that yield loss compared to autumn harvest is 40% (Lindh et al., 2009). Net energy yield as the indicator of land use efficiency is calculated as the difference of total energy yields and total energy input. Energy use efficiency is the ratio of net energy yield to energy input. Reed canary grass yield and land use efficiencies increased with increasing energy input. The average DM yields varied from 2.7 to 9.5 t ha⁻¹ y⁻¹. Previously estimated high reed canary grass yields (7–8 t ha⁻¹ on clay soils) (Saijonkari-Pahkala, 2001) could be reached on soils with low humus content using fertilisers more than 200 kg ha⁻¹ in which case also the environmental restrictions should be taken into account. The variation coefficient in unfertilised plots exceeds the variation in the areas with increased fertiliser input. So the higher nutrient supply is, the more stable are reed canary grass yields.

The net energy yield varies from 11 to 38 GJ ha⁻¹ in unfertilised plots and 60 to 101 GJ ha⁻¹ in fields where N 360 kg ha⁻¹ were applied. The average energy use efficiency increases to an input level of 12.7 GJ ha⁻¹ reaching efficiency 5.2 GJ GJ⁻¹ and then decreases to the level of 4.1 GJ GJ⁻¹ with input requirement 18.5 GJ ha⁻¹. For reaching optimum energy use efficiency level nitrogen fertiliser should be used 198 kg ha⁻¹, which arises the issue about environmental protection.

References


Information and Communication Technologies and biomass Supply Chain Management

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The raw materials for biomass conversion are produced over large geographical areas, have limited availability, and are often handled as very voluminous materials. Therefore, an effective and optimized supply chain is required. The transportation and logistics between the point of production and to the conversion facilities becomes a vital part of the overall operational, economic and energetic viability of the biomass conversion process.

The necessary requirements include a reliable and optimised infrastructure capable of supplying biomass components to be fed into the conversion plant in the right quantity and at the right time. Thus, the supply chain must comprise optimised steps of harvesting biomass crops, collecting biomass residues, storing and transporting of biomass resources. Robust and intuitive, mobile information devices are employed today in all areas of supply chain management, from planning and production to warehouse and transportation (Allen et al. 1998). Logistics today involves managing a wide range of business partners and passing information from partner to partner in a sequential form is simply not good enough. In response, companies are replacing traditional, linear supply chains with adaptive supply chain networks in which partners are dynamically and simultaneously given accurate information about demand, supply and operational activities. The mobile capabilities provide a convenient, time-saving, and highly accurate means of capturing data on movements of goods and other events.

From the IT perspective, a new wave of solutions is arising with the main type to overcome all the physical, organizational and informational hurdles. Advanced planning and scheduling (APS) systems aim to step over the intra-company integration supplied by Enterprise Resource Planning (ERP) systems by providing a common inter-organizational SCM platform, which supports the logistics chain along the whole product life-cycle, from its initial forecast data, to its planning and scheduling, and finally to its transportation and distribution to the end consumer (Kosturjak et al. 1999).

References

Business Showcases

DAKA: Biodiesel from Agricultural bi-products

DAKA biodiesel is a high-technology company that produces and markets environmental friendly high-quality biodiesel and biofuel oil on the basis of agricultural by-products. The first Danish 2nd generation biodiesel plant is now producing with a capacity of 55 million litres per year and is prepared for expansion. Biodiesel can be used in diesel engines and for heating. The European EN 590 allows for 5% biodiesel, but many cars, trucks and busses can use 100% biodiesel with minor technical adaptation. For five years Daka has used biodiesel in its own truck fleet (2,000 trucks).

Daka converts refined animal fats derived from residues from abattoirs and primary agriculture. Moreover, Daka uses frying fats and fish oils that are unsuitable as food as raw materials for biodiesel.

The biodiesel plant is supplied by BDI, an Austrian company with extensive experience in setting up biodiesel plants based on animal fat. Furthermore, the SARIA ownership has ensured supply of a key knowledge since this company has established and operates several biodiesel plants in Germany.

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LIN-KA: Biofuel Heating and Steam Plants

Over thirty years of experience and know-how on the combustion of biomass make LIN-KA ENERGY A/S one of the world leaders within biofuel heating and steam plants, particularly within the utilisation of straw, pellets, woodchips and other types of biomass.

In recent years, LIN-KA has opted to gain a presence on the export markets through a network of partners.

When it comes to the environment, LIN-KA ENERGY A/S helps reduce CO2 emissions each time one of its plants is set up to replace existing fossil fuel units – the vast majority at this time.

LIN-KA was founded in 1975 and has a yearly turnover of DKK 10-100 million.

References
Textilia Rimbo, 5MW wood pellet fired steam boiler operating at 16 bar pressure
Skarrildhus, 400kW wood chip fired system for heating up hotel and conference facilities
Nimtofte Varmeværk, 5MW straw fired district heating plant

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Grundfos BioBooster and NH4+ Slurry Acidification Systems

Grundfos
The Grundfos Group, based in Denmark, was founded in 1946 and is a global market leader within the pump industry. In 2006, turnover reached EUR 2.06 billion, with a profit before tax of EUR 198 million. The Grundfos Group employs approximately 14,800 persons in 75 companies in 42 countries worldwide.

Production exceeds 14 million pump units annually. Grundfos solutions are employed in NOx emission reduction, biological wastewater treatment, heating, water supply, wastewater, air conditioning, dosing, pressure boosting, and fire fighting. We take our global responsibility for the environment very seriously, working to create sustainable solutions that make the world a better place to live. We do so with our three core values of “Be responsible-Think ahead-Innovate” at the heart of all we do.

Infarm
Infarm A/S is a Grundfos company. Infarm develops, produces, sells and services environmental technology for intensive agricultural production. The main technology is the NH4+ slurry acidification concept, where pH in the manure is lowered from approx. 7.5 to 5.5. By the process, the ammonia in the manure is bound as ammonium, thereby reducing ammonia emission from both stable, storage and field application significantly. As such, the nutrient-value of the manure is saved to the field crops and increased crop yield can be achieved. Besides these positive effects, the pH reduction also reduces the unintended production of methan from the slurry storage. Subsequently, the technology solves two of the most predominant environmental impacts of modern intensive livestock production.

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Samson Bimatech: Slurry separators and energy plants

Samson Bimatech is a modern, innovative company focusing on development and production of slurry separation technology. Our company is located in the small town Tange near Bjerringbro in the heart of Jutland (Denmark).

Samson Bimatech is part of Samson Group A/S which is an international organisation that also includes Samson Agro A/S. Samson Agro A/S is producing machines and equipment for outdoor handling of manure. For further information please visit www.samson-agro.com.

Our well-motivated staff is working closely with our customers to make sure that we develop the best technology for the agriculture and provide our customers with a competent and professional service. As we say: Samson Bimatech - taking agriculture to a higher level.

From several years of development work, Samson Bimatech has gained experience that forms the foundation of our products within slurry separation.

Slurry separation will remove the solid parts of your slurry by separation and use the remaining liquid part as a well-optimized fertilizer product that allows you to increase the amount of slurry per hectare. Samson Bimatech has developed a unique energy plant on farm scale with slurry separation, drying and incineration of fibres to produce heat.

Please visit www.samson-bimatech.com to find references for separators and energy plants.

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AgroTech: At the cutting edge of knowledge and technology transfer

AgroTech is established in order to strengthen development and the use of knowledge and technology within the food and agricultural sector. AgroTech is a member of GTS – a network of independent Danish research and technology organisations. The members of this network have been authorised as technological service institutes by the Danish Ministry of Science, Technology and Innovation. We carry out tests, development and demonstrations within crop production technology, biomaterials and bioprocess technology, environment and energy technology, the animal and food area, information and communication technology as well as technology within the horticultural business.

We focus on sustainable production of food and other biobased products. Our fields of expertise cover agriculture and food, and our knowledge of biology and technology allows us to perform tasks within the entire value chain from primary production to final consumption.

Our competences cover all links in the value chain. We develop innovative and commercial solutions for the food industry, nurseries and suppliers to the agricultural industry. We co-operate broadly with both Danish and foreign businesses and knowledge institutions. We want to be the natural first choice when it comes to business development within agriculture and food production and we have an aim to turn Denmark into a global powerhouse within development of future commercial production of food and other biobased products. Our domicile is in Skejby near Aarhus and at present we have approximately 80 employees.

References
Gartneriet Hjortebjerg, Steen Thomsen, Reduction of energy consumption:
- AgroTech manages our development projects and keep them on track. The employees are also excellent at finding partners who match out criteria and at contacting public authorities, ensuring a solid financial foundation.
Skiold A/S, Peter Stougaard, Biofilter technology:
- AgroTech is a new and dynamic company. The employees are very committed and highly skilled. They provide specialized knowledge to companies which are converted into commercial solutions. We have an excellent and a very fruitful relationship with them

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Søren U. Larsen, innovation adviser, phone +45 8743 8425, cell +45 3092 1708, fax +45 8743 8410. sol@agrotech.dk. Languages: English, Danish
NatLan: Biomass from meadows for Biogas

NatLan Aps, founded in 2004, works for a possible win-win situation: Combination of nature management and agricultural production. Therefore, NatLan focuses on 1) biomass production in meadows, 2) biomass suitability for biogas and 3) collection of nutrients from riverside areas through harvest of biomass. Project managers at NatLan have a long experience in management of nature in riverside areas.

We focus on influence of management on plant species composition, on forage quality or quality as substrate for biogas production. The quality is dependent on species composition as well as time of harvest. We also deal with stepwise management strategies to improve nature quality in agriculturally influenced permanent grasslands.

References
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AgroTech A/S – Evaluation of biomass production and environmental benefits from riverside areas along river Nørreå with different vegetation types.

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At the Faculty of Agricultural Sciences, Aarhus University extensive R&D on the biogas technology is in progress with the aim of increasing biomass conversion efficiency, decreasing reactor retention time, and securing a better online process monitoring. The conditions for research and development in this area have been strongly improved by the recent inauguration of the world’s largest experimental biogas facility at Research Centre Foulum. Also experiments on the production of second-generation bioethanol and on the utilisation of biogas in fuel cells are carried out here.

Examples of cooperation between the Faculty of Agricultural Sciences and companies would typically be within research, development and innovation in connection with technologies for production, handling of biomass and for conversion to bioenergy. Furthermore, the faculty has broad knowledge on feedstock quality and is able to deliver a range of qualities for testing their conversion feasibility.

The Faculty of Agricultural Sciences has research activities at four centres and at four experimental stations. Furthermore, a research group is located at the Faculty of Life Sciences, University of Copenhagen. The Faculty of Agricultural Sciences thus has modern laboratories and experimental facilities including barns, greenhouses and semi-field facilities. The Faculty of Agricultural Sciences has approximately 9,00 employees, of these approximately 375 scientists, distributed on the different centres and localities. The annual turnover of The Faculty of Agricultural Sciences is DKK 700 million.

Please visit www.agrsci.org for further information.

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